Watermarking of color images is studied in this research work to authenticate them and copyright protection. The aim of this thesis is to develop efficient watermarking algorithms for color images and video in order to achieve high imperceptibility and robustness without losing color content of recovered watermarks.

In this chapter, comparison of simulation results of all the proposed color image watermarking schemes is presented. This chapter summarizes the work presented in this thesis and also presents directions for future work.

7.1 Comparative Analysis

Proposed algorithms have been evaluated based on the properties of imperceptibility and robustness. Limitations of each watermarking scheme are discussed. To overcome those limitations, how advanced schemes are developed till highest transparency achieved is also briefed.

The comparison of improvement of performance in terms of PSNR for all the proposed non-blind invisible color image watermarking schemes is shown in Table 7.1. From this Table, it can be inferred that the proposed hybrid color image watermarking scheme using DWT-DCT-SVD gives better imperceptibility when compared to other two SVD based and DWT-SVD based methods.

<table>
<thead>
<tr>
<th>Cover images</th>
<th>SVD</th>
<th>DWT-SVD</th>
<th>DWT-DCT-SVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peppers</td>
<td>34.1822</td>
<td>57.7293</td>
<td>64.8281</td>
</tr>
<tr>
<td>Lena</td>
<td>31.6528</td>
<td>56.3959</td>
<td>63.4503</td>
</tr>
<tr>
<td>Sunset</td>
<td>32.9373</td>
<td>56.6437</td>
<td>63.8058</td>
</tr>
<tr>
<td>Balloon</td>
<td>29.9773</td>
<td>56.3841</td>
<td>63.5530</td>
</tr>
<tr>
<td>Autumn</td>
<td>34.1189</td>
<td>58.7554</td>
<td>65.9654</td>
</tr>
</tbody>
</table>
The embedding capacity also enhanced with this scheme that varies image to image with selected transform technique for color image watermarking. According to the size of cover image and watermark image, the capacity of the proposed scheme increases.

The measurement of visual quality in terms of PSNR for three different algorithms is graphically shown in Fig. 7.1. Among the three algorithms, third one shows the superior performance in terms of imperceptibility and robustness as explained in chapter 5. This algorithm is used for video watermarking to attain very good perceptual quality and robustness in addition to more capacity against intentional and unintentional attacks as described in chapter 6.

![Fig. 7.1: PSNR values of three different algorithms for various cover images](image)

**7.2 Conclusions**

In this research work, three different watermarking methods for color images have been developed and implemented to achieve good invisibility, to start with, SVD based algorithm is implemented to embed gray scale image in color host image, which is defeated in maintaining the perceptual quality and payload is also limited.
To overcome these limitations, DWT-SVD based algorithm is implemented to hide color logo in color host image. It has been proved that this algorithm is successful in detecting the watermark but failed in retaining the color of extracted watermark under distortion. Thus to restore the color of the watermark extracted from attacked watermarked media, an improved hybrid algorithm has been developed using DWT, DCT and SVD. According to the application, the algorithm aims to target the specific requirements of watermarking algorithm will vary.

The watermarking methods have been compared with each other in terms of their perceptibility and robustness. The methods have been exposed to several simulation tests checking up their resistance to various types of attacks. All the methods are more or less resistant to simple attacks such as noise, filtering, compression and contrast adjustment. Among all projected watermarking methods, the hybrid watermarking scheme based on DWT-DCT-SVD shows superior performance and more robustness to common image processing degradations including compression, Gaussian noise, salt & pepper noise, median filtering, average filtering, sharpening, histogram equalization, rotation, cropping without degrading perceptual quality of watermarked data and the color information in retrieved watermark. After achieving the best perception and robustness with hybrid color image watermarking, this is extended to color video watermarking for embedding gray scale and color logo images.

Hybrid video watermarking algorithm proves that multiple watermarks can be embedded in selected group of frames without affecting the human perceptual quality of watermarked video. It can handle huge watermark data to hide and gives good imperceptibility. It is also proved that this algorithm can withstand all intentional attacks like frame averaging, dropping and swapping in addition to common signal processing attacks. Though the watermarked video is troubled with attacks, color of the retrieved watermark is preserved as it is using this hybrid algorithm. With the proposed hybrid video watermarking scheme, good tradeoff is maintained between imperceptibility, robustness and hiding capacity.
7.3 Scope for Future Work

In future, the present work can be extended to combine audio watermarks with video to enhance the robustness. For audio watermarks with video, the proposed approach needs development of separate algorithm.

For further improvement of performance, decomposition can be done at multiple levels. To defeat the limitations of non blind watermarking techniques, experiments can be carried out on the proposed scheme to make it a blind scheme that means it will not require the original data while extracting the watermarks. And the present hybrid technique is also used for visible watermarking in robust way which is important for online resources to identify the owner visually.

Though the proposed hybrid watermarking scheme is resilient against various attacks, the value of correlation factor is not that much good for Gaussian noise attack and Salt & Pepper noise attack compared to other attacks. Even this algorithm is able to retrieve the color of the watermark, it is further enhanced to improve the correlation factors against noise attacks. Still there are scopes to improve this work that is the watermarking scheme given in this thesis can be further improved to increase the security of watermarks without affecting the imperceptibility of the images.

Digital watermarking is not just limited to the traditional media like image, audio and video, it can be applied to three dimensional data. The importance of this research increases significantly as the technologies like 3D computer aided drafting (CAD) have advanced.